REMARKS-General

Amendments

The applicants have amended the claims so as to overcome the examiner objection that the recitation "a motor positioning servo loop" has not given patentable weight because the recitation occurs in the preamble.

Claims 1 through 6 have been canceled and claims 7 through 12 are the new claims. Claim 7 is now the first independent claim (replacing claim 1) and claims 8 through 12 are the new dependent claims.

Claims 13 through 18 are new claims and define a method for achieving high resolution control of a system by means of a motor positioning servo loop utilizing an oversampling signal conversion according to the patent application specification, drawings, abstract and title.

The applicants concur with the examiner that the main independent claim 1 did not clearly define the motor positioning servo loop of the subject invention. The body of the claim could not explicitly differentiate the subject invention from the general system described by Bibyk (6,202,198) in his Figure 1.

The structure of the "motor positioning servo loop" is now completely defined in the body of the main independent claim (claim 7) as a feedback loop with five main elements: the microcontroller, the oversampling digital to analog converter including

its digital oversampling modulator, the motor actuator, the motor itself and the detector of the kinetic physical parameters (like position, velocity and acceleration) of the controlled system. The purpose of the motor servo loop, in its feedback configuration, is to control these physical parameters in order to achieve the desired actuation.

Furthermore the body of the new claim 7 now does not depend on the preamble for completeness, therefore the applicants request reconsideration of the rejected claims.

In compliance with 37 CFR 1.21, all the new claims directly follow from the teaching described in details throughout all the patent application specification, drawings, abstract and title. None of the new claims introduces new elements or concepts not directly derived from the specification of the published application.

Response to Office Action

The new claim 7 specifically describes a feedback system to provide electrical energy to a motor by means of a servo loop that controls its position, velocity or acceleration, where the oversampling nature of the data converter is essential to the novelty of the invention.

The examiner cites portions of the reference Bibyk from its "Background of the Invention" section and combines these citations with the Fig.1 described in details in the "Detailed Description of the Invention" section.

The applicants contend that the system described in Fig.1 is not directly related to the general status of the art for mixed signal electronics described in the Background of the Invention.

The applicants maintain that Bibyk, in its Background of the Invention section, discusses in very general terms the status of the art of mixed signal electronic system with particular reference to codecs for speech and video systems.

Although making reference to very general electronic systems, Bibyk (col.2 ¶ 9-29) clearly teaches that Sigma-Delta converters are used in speech and video systems. Furthermore, in the whole Background of the Invention section, there is neither mention of feedback systems nor of motor positioning servo positioning control loops. As far as the reference to the drive of an actuator (col. 1 ¶ 52-57) the examiner notes:

> *Thus, when Bibyk speaks of a physical result or phenomenon being the motion of a motor or loudspeaker, this means that the motor or loudspeaker is simply part of the speech or video system.*

The applicants agree with the examiner's conclusion that the motor or loudspeaker is intended for speech and video systems which knowingly make no use of complete electronic feedback systems. The typical example being the telephone system.

Conversely, the cited Figure 1 of Bibyk is described in details in the "Detailed Description Of the Invention" section (col. 5 ¶ 8-57). Once again, in this very general description no reference to a motor positioning servo loop has been made; Bibyk discloses a very general electronic system without making reference to the specific

control of the motor's kinetic physical properties. Again the applicants contend that the system described in Fig.1 is not a typical electronic feedback system like a motor positioning servo loop, rather a system where the physical phenomenon is not defined and it may be construed as the user of the telephone system that listens to the output of the loudspeaker and reacts speaking into the microphone thus, in a very limited sense, "closing the loop". Furthermore, it is important to note that in the whole detailed description of Figure 1, the digital to analog converter is not described as an oversampling converter.

As far as the rejection of claims 2, 3 and 6 the applicants contend that the new claim 7 is differentiating the subject invention from the reference Bibyk to adequately overcome the rejection of the claims for obviousness under 35 U.S.C. 103(a).

The applicants have carefully reviewed all the other references cited by the examiner and listed here:

Contreras (6,154,017)

Pedrazzini (6,735,540)

Masuda (6,304,200)

Tanzer (5,284,342)

Nilsson (6,724,249)

Nilsson (6,842,070)

Galloway (6,246,536)

The applicants have concluded that, though constituting pertinent prior art, none of the above references anticipates in whole or in part the subject invention.

The claim rejection under 35 USC §102.

The claims 1, 4, and 5 were rejected as being anticipated by Bibyk (US 6,202,198).

Applicants request reconsideration of this rejection for the following reasons:

1 Novelty of the subject invention over the cited prior art reference

The prior art reference lacks elements claimed in the present invention. Reference Bibyk describes, as prior art, a very general system of processing a signal with digital means and driving an actuator, similar in some respects with the subject invention, but it clearly distinguishes from the subject invention for the following aspects:

1.1 The cited reference does not refer to motor control servo systems.

In Bibyk, Figure 1, the disclosed block schematic diagram is a conventional analog sensing system with conversion to digital format, treated by digital computer and returned to an analog output (col.4, ¶ 36-39). These systems are generally implemented with complex circuits that sense voice and or images whose analog signals are converted into digital and processed by full computer systems before being reconverted into analog signal for the actuator. The typical example is the telephone system which comprises a microphone (represented by the sensor of FIG.1), the entire telecommunication system (represented by the circuit 18 of FIG.1) and the telephone loudspeaker (represented by the actuator of FIG.1). The generic block 10 indicated in FIG.1 as "Physical Phenomenon" would be represented by the user of the telephone device. The use of oversampling converters, especially in the area of audio signal processing where the required signal bandwidth is limited, certainly represents prior art being a very conventional means of converting signals. The cited reference does not make mention of motor positioning or general control systems, where kinetic physical parameters like position, velocity and

acceleration are tightly controlled to operate systems like hard disk drives, optical data storage devices, printer motors and robotics actuators.

1.2 The cited reference does not refer to closed loop systems.

The system described in Bibyk is not a conventional electronic closed loop system as, in fact, it specifically refers to codecs devices (col.2, ¶. 25) circuits used in the areas of speech and video systems (col.2, ¶. 24). Bibyk fails to teach how the prior art system of FIG.1 could be construed as a closed loop system and more specifically as a servo loop. The presence of a closed loop system to accurately control the kinetic physical parameter of the system, as described in the subject invention, is not represented in Bibyk, and certainly one skilled in the art can not directly infer that the signal processing system described in Bibyk could encompass a motor positioning servo loop implementation.

One skilled in the art relating to closed loop systems and servo systems in particular would recognize that the most important part of the servo system relates to measuring and controlling a physical quantity. The generic "cloud" in Bibyk figure 1, relating to the physical world clearly disclaims any concern on Bibyk's part for any art related to what might be necessary to convert his signal processing system into a mechanical closed loop system. It would have been straightforward to express some generic feedback path from output back to input, and Bibyk chose not to do so. The system examples, (e.g. a telephone system where the physical input is microphone and output is a loudspeaker) are clearly chosen to reinforce the input-to output flow and exclude any

interpretation of the presence of feedback, in the control system sense, between input and output. (Even in the telephone example, since the system shown would be from one customers mouthpiece to another customer's earpiece, a more liberally defined form of "interpersonal feedback" would require a second transmission path from the second customers mouthpiece back to the first customer's earpiece).

Were Bibyk describing a system suitable for creating a control system, that system would need a control signal. A control input, a control signal, a reference level, or some other means of determining to what value the physical phenomenon in the physical world should be controlled would be required, else there would be no mechanism to actually set the value of the output (the whole point of the control loop).

In order to be interpreted as a feedback system, the purpose of the "input" of FIG. 1 would be to gather feedback information. In its description and its lack of indicated correlation to the output, it appears clear that the input of FIG. 1 would be a "control signal" input, and that the system then drives a physical output open loop. Bibyk's description of the system is that "a physical phenomenon is sensed and then acted upon" (column 5, lines 10-11). This is explicitly an open loop system as described.

1.3 The cited reference makes use of an analog to digital converter not used in the subject invention.

Generally magnetic and optical data storage devices do not include an analog to digital converter because the kinetic parameters of an element of the motor are detected through the readings of the data on the media. The servo signal is therefore in a digital form (without the need for a conversion) and after being processed is converted by a digital to analog converter to drive the motor in order to control position, velocity and acceleration. This represents a further major difference with cited reference Bibyk, for which the system of FIG.1 and the description in the background of the invention clearly differentiate from the subject invention.

1.4 The cited reference makes use of a common digital interface (Computer Interface) for the input path and for the output path not used in the subject invention.

As described in subject invention, the input signal path and the path from the microcontroller to the motor actuator are not linked. In the specific case described in the specification, the control of a voice coil motor in a disk drive, the feedback position error digital information is a digital signal that the servo system receives from the read/write channel, and the forward path to the motor drive is through what is known as the "combo chip", being a separate and distinct signal path from the microcontroller. The common I/O path is appropriate for a codec as described by Bibyk, reflective of the inherent difference between signal processing codecs and servo control loops.

1.5 The cited reference makes explicit reference to audio and video systems.

The microprocessor utilized in the motor positioning servo loops of modern data storage devices are mainly formed by two major blocks: the signal detection circuit and the data controller. The signal detection circuit decodes the signal from the media, while the data controller converts the digital data for the transmission to the bus on the host computer. Only a small portion of these digital data represents the signal for the motor control servo loop. In a very dissimilar way, the cited reference Bibyk makes explicit reference to audio and video systems where the digital signal is processed and mainly compressed combining it with mu and A-law encoder functions (col.2, ¶. 20-24) by a digital computer. This represents a further major difference with cited reference Bibyk, for which the system of FIG.1 clearly differentiates from the subject invention.

1.6 The cited reference makes explicit reference to the use of decimation filter.

The subject invention teaches throughout its specifications that an important novelty feature is the utilization of a digital implementation of the oversampling modulator directly coupled to the motor actuator without the common requirement for decimation filters utilized in conjunction with traditional oversampling converters. The low frequency mechanical response of the motor is reflected in an equivalent low pass filter in order to guarantee stability of the control system. This low frequency pole embedded into the motor actuator

eliminates the need for an additional decimation filter that could add delay or cause system instability. The cited reference makes explicit reference to the use of decimation filters (col.2, ¶. 18-28). This represents a further major difference with cited reference Bibyk, for which the system of FIG.1 and the description in the background of the invention clearly differentiate from the subject invention.

Therefore the applicants submit that the cited reference (Bibyk) does not anticipate the subject invention and that the use of oversampling converters in motor positioning servo loop systems, as described by the new claims, is novel.

2 The cited reference does not combine the Background of the Invention with the system described in Fig.1.

The examiner cites portions of the reference Bibyk from its "Background of the Invention" section and combines these citations with the Fig.1 described in details in the "Detailed Description of the Invention" section.

The applicants contend that the system described in Fig.1 is not directly related to the general status of the art for mixed signal electronics described in the Background of the Invention and therefore an extrapolation of the features described in the general state of the art of electronics into the more particular case of Fig.1 is not warranted.

2.1 Analysis of the Background of the Invention of reference Bibyk.

The applicants maintain that Bibyk, in its Background of the Invention section, discusses in very general terms the status of the art of mixed signal electronic system with particular reference to codecs for speech and video systems. As pointed out by the examiner, Bibyk discloses a Sigma-Delta converter (col.2 ¶ 9-29):

> Very often, the analog circuits are combined with digital circuits, i.e., in integrated circuits referred to "mixed mode" devices. The interface between analog and digital regimes is through analog to digital (A/D) or digital to analog (D/A) converters. Most commonly, these devices perform with multi-bit parallel words, i.e., sixteen, thirty-two or sixty-four bit word systems, the multiple lines of which consume a substantial area of silicon on a chip. There are, however, several methods of analog to digital or digital to analog conversion, i.e., Sigma Delta converters which, for example, combine oversampling with decimation filtering in an input analog to digital configuration. The bit stream outputs of those input features then are combined with mu and A-law encoder functions the development of which has been based upon what amounts to decades of investigations into specific areas of use, i.e., speech, and video systems. These integrated circuits conventionally are referred to as codecs. Their output from digital to analog performance typically

> utilizes an expanding interpolation filter, a sigma Delta digital to analog converter and filtering. For the present, codecs are application specific.

Although making reference to very general electronic systems, Bibyk clearly teaches that among the several types of data converters used, the Sigma-Delta converters are implemented in speech and video systems. The explicit reference to the fact that the bit stream outputs are combined with mu and A-law encoder functions leaves no space to any other interpretation for the usage of the sigma-delta converters. Different interpretations certainly cannot be ascertained by the cited reference.

Furthermore, in the whole Background of the Invention section, there is neither mention of feedback systems nor of servo positioning control loops. As far as the reference to the drive of an actuator (col. 1 ¶ 52-57) the examiner notes:

> *Thus, when Bibyk speaks of a physical result or phenomenon being the motion of a motor or loudspeaker, this means that the motor or loudspeaker is simply part of the speech or video system.*

The applicants agree with the examiner's conclusion that the motor or loudspeaker is intended for speech and video systems which knowingly make no use of complete electronic feedback systems. The typical example being the above mentioned telephone system.

2.2 Analysis of FIG.1 of reference Bibyk.

The cited Figure 1 of Bibyk is described in details in the "Detailed Description Of the Invention" section (col. 5 ¶ 8-57). Again, in this very general description, no reference to a motor positioning servo loop has been made; Bibyk discloses a very general electronic system without making reference to the specific control of the motor's kinetic physical properties. Again the applicants contend that the system described in Fig.1 is not a conventional electronic feedback system like a motor positioning servo loop, rather a system where the physical phenomenon is not defined and it may be construed as the user of the telephone system that listens to the output of the loudspeaker and reacts speaking into the microphone thus, in a very limited sense, "closing the loop". Furthermore, it is important to note that in the whole detailed description of Figure 1, the digital to analog converter is not described as an oversampling converter.

3 Novelty of the subject invention.

The novelty of the subject invention resides in the fact that oversampling data converters are used in motor positioning servo loop systems and that constitutes an innovative method of achieving high performance in the control of the kinetic physical parameters of the motor without introducing extra manufacturing costs. Existing prior art, as cited in the subject application, describes the use of data converters in servo loop systems, but these converters are always implemented utilizing the conventional Nyquist-rate type of digital to analog converters.

Similarly the use of oversampling digital to analog converters is common in other totally different types of system, particularly in speech and video signal processing applications and nonanalogous to the motor control servo loop applications. Furthermore the digital implementation of the oversampling modulator allows the integration of the converter in the microcontroller as a hardware or software structure, since the common decimation filter used for oversampling converters is not needed. The filtering action embedded in the motor actuator low frequency response is adequate to warrant the elimination of a traditional dedicated decimation filter.

The digital implementation of the oversampling modulator embedded into the microcontroller either as a hardware or as a software structure is certainly not obvious since the high oversampling frequency requirement imposes a severe bandwidth limitation that made it unimaginable or impractical until a few years ago and still not feasible with most of today's conventional microcontrollers.

Based on the above-mentioned reasons the applicants submit that the cited reference (Bibyk) does not anticipate the subject invention and that the New Claims are allowable over the cited reference and respectfully solicit reconsideration and allowance.

The claims rejection under 35 USC §103.

4 Rejection of claims 2 and 3.

The claims 2 and 3 were rejected as being unpatentable over Bibyk as applied to claim1 and in further view of Galloway (6,246,536).

Galloway discloses a means for providing improved attenuation of the mechanical resonant frequencies in a disc drive by means of notch filtering the actuator driving signal. Galloway also states that the invention is also applicable to optical disks.

The specification of the subject invention makes specific reference to servo loops for Hard Disk Drives systems. Many other examples of servo loops in optical disks systems are known prior art. Galloway is clearly one of these examples.

However Galloway, though describing a motor positioning servo loop system, throughout its patent specifications never makes reference to the use of an oversampling data converter in the loop.

The examiner contends that it would have been obvious to one having ordinary skill in the art at the time of the invention that the motor actuator of Bibyk would be driven by a VCM in an optical data storage device actuator because of the advantages provided by implementing a sigma-delta DAC into an optical data system.

The applicants have written the new claim 7 to differentiate the subject invention from the cited Bibyk reference as discussed above, therefore the applicants request reconsideration of these rejections for the following reasons:

4.1 Prior art Bibyk is nonanalogous art.

The cited reference Bibyk describes a conventional analog sensing system with conversion to digital format, treated by digital computer and returned to an analog output (col.4, ¶ 36-39). This system is not a closed loop system as, in fact, it specifically refers to codecs devices (col.2, ¶. 25) circuits used in the areas of speech and video systems (col.2, ¶. 24). The subject invention specifically refers to motor control servo systems whose mere function is to drive the motor in order to accurately control its position, velocity and acceleration. Therefore Bibyk (US 6,202,198) is from different field and it is to be considered nonanalogous art (M.P.E.P. § 2141.01). Furthermore the reference is not reasonably pertinent with the problem that the subject invention addresses.

4.2 Lack of implementation.

With respect to claims 2 and 3, the enumerated advantages of the subject invention in the field of magnetic and optical data storage devices would lead to the consideration that if the implementation of oversampling data converters were obvious to one having ordinary skills in the art at the time of the invention, then they should also have been obvious for well over a decade. Considering the fact that oversampled converters have been well known for more than two decades, and are well known to have driven digital audio systems, for instance, to lower cost even as the accuracies have increased (16 bit, 44.1 kHz converters for CD format audio are still quite expensive using conventional A/D

and D/A technologies, but sigma-delta systems for 96 kHz, 24bit systems are available in low cost consumer electronics). It is inexplicable that their use in servo systems, if it were obvious, is completely unknown. The fact that, as of today, people skilled in the art, other than the applicants and the prospective licensees, have not implemented the subject invention despite its numerous and significant advantages, indicates that it is **not obvious**.

4.3 Impermissible hindsight.

The applicants have contacted several large corporations in the business of motor control for several applications to discuss the validity of the subject invention and possible licensing of the technology and found no evidence that the use of oversampling converters for motor control servo loop system could have been considered obvious by anyone skilled in the art. The conceptual technological leap to use oversampling data converter for motor control servo loop is significant. The Examiner conclusion of obviousness is based on improper hindsight reasoning (M.P.E.P. § 2145.X) The applicants argue that the Examiner does not take into account only knowledge which was within the level of ordinary skill in the art at the time the claimed invention was made and that the Examiner includes knowledge gleaned from the applicant's disclosure.

4.4 The motivation supporting the rejection of claims 2 and 3 under 35 U.S.C. 103 (a) is based on an erroneous assumption.

The examiner has inexplicably contended that

> *implementing a sigma-delta DAC into an optical data system provides the advantage of shifting unwanted signals to higher frequencies so that unwanted signals can be filtered using low-pass filtering*

The unwanted components to the signal that get shifted to higher frequencies by the oversampling converter of the subject invention are not present in the conventional converters used in these mentioned magnetic and optical data storage systems. The use of Nyquist-rate conventional data converters does not generate high frequency quantization noise therefore, the reasoning that the use of oversampling data converters to shift unwanted signals to higher frequency is obvious to anyone skilled in the art, is clearly not consequential. On the contrary, the high frequency quantization noise generated by oversampling types of converters **makes the subject invention clearly unobvious** due to the concerns of additional filtering, possible electro-magnetic interference and electrical disturbances of various nature, issues particularly troubling in the case of data storage devices.

5 Rejection of claim 6.

The claim 6 was rejected as being unpatentable over Bibyk as applied to claim1 and in further view of Contreras (6,154,017).

Contreras discloses a means for optimizing an equalization and receive filter of a read back system of a storage device in order to minimize the probability of error in

the read channel system. The examiner notes that Contreras (col. 5, ¶18-20) teaches:

> Adder 330, optimizer 340, and bank of DACs 350 can be implemented completely in hardware or firmware, software with a microcontroller or a microprocessor, or any combination thereof.

However the examiner fails to recognize that these types of digital to analog converters used in the read channel systems, certainly **cannot** be implemented as oversampling data converter due to the extreme speed requirements of the system. The use of oversampling converters in the read channel is certainly not possible with todays technology as well as in the foreseeable future in hardware. The examiner can concur that if the implementation of these converter is **not feasible in hardware, it is certainly not even imaginable in software**.

Furthermore the applicants have written the new claims to differentiate the subject invention from the cited Bibyk reference as discussed above, therefore the applicants request reconsideration of this rejection.

The rationale supporting the rejection under 35 U.S.C. 103 (a) of claim 6 pertaining to the implementation of the oversampling digital to analog converter in software within the microprocessor, although expressing a valid and advantageous motivation, does not constitute a valid argument for obviousness of claim.

6 The present invention gives utility not present in any cited prior art.

The use of oversampling digital to analog converter in motor positioning servo loops is novel and unobvious resolving the problem of controlling with higher resolution the actuator reducing significantly the development and manufacturing costs. No cited prior art includes this functionality.

Taken separately or in combination, no prior art has been disclosed, and no combination or extrapolation of combinations of prior art has been suggested, which provides the utility of the subject invention.

7 Unobviousness of the subject invention.

It is well accepted by those skilled in the art that sigma-delta and related converters, although ideally suited for signal processing applications, are generally inappropriate for closed loop servo-systems. There are several well-known problems.

First, latency, or time delay, is a considerable problem in closed loop systems as it makes loop stability difficult and thereby limits performance. Bitstream converters, and particularly bitstream A/D converters, can exhibit relatively wide bandwidth, but the high-order digital filtering typically used to convert the oversampled bitstream to a nominally sampled digital word of 8-24 bits imposes a significant fixed delay. (There are many implementations which yield effectively zero relative phase shift desired signal bandwidth, but this is accomplished by having a large but constant time delay across the entire bandwidth – which yields vexing problems for closed loop stability).

Second, when the signal of interest is represented as a bitstream, there is an AC noise component that is equal to that of a signal swinging back and forth between

positive and negative full-scale. To make matters worse, this noise is spread across a wide bandwidth to very high frequencies, giving great concern for the interaction between this noise and a variety of signals and systems. For these and other reasons, sigma-delta converters are universally believed to be applicable to signal, but not servo-control applications.

Because of the well-known presumption of inapplicability of bitstream converters to this field, in the prior art, the applicants find no reported implementations of control loops using oversampled bitstream converters. Considering the multi-decade maturity of these converter techniques in signal applications, as well as their well-known benefits in cost and performance, the complete absence of this technique from servo control systems is testament to the fact that it is clearly **not obvious, to those practicing this art, that bitstream converters are appropriate for this purpose**.

In the development of the present invention, the concern over anticipated problems relating to oversampling D/A conversion within the servo-system has been found to be groundless. In the reduction to practice, a sigma-delta modulator, implemented digitally, to convert the digital commanding signal into a high frequency oversampled bitstream was utilized. The maximum bandwidth of the system is one half the frequency at which the commanded value is updated, in this case in the low kilohertz range. But the latency of the digital modulator is on the order of at most a couple cycles of the much higher oversampling clock, which was experimentally verified up to several Megahertz. Hence, the digital to bitstream conversion can be seen as adding virtually no latency to the signal, certainly no more than the settling time of the traditional Nyquist rate DACs presently used.

In practice, there is a very high value of switching noise included in the bitstream. Initial reaction by most engineers to which the present invention has been disclosed is that this noise will likely make the approach unworkable. But because all of this high frequency noise is significantly outside the bandwidth of the loop, reasonable precautions to prevent either radiating this signal to sensitive analog nodes and to prevent the system from reacting nonlinearly to the large peak value of the noise are sufficient to allow the system to act linearly to only the low frequency signal information and completely filter the out of band noise.

The applicants have been working in particular, as explained in the specification, in the area of disk drive VCM control (the linear motor that positions the read/write head). In present systems, the most critical analog component in the combined integrated circuit that implements the control and motor actuator is the DAC. A precise DAC needs large arrays of precision matched analog elements as well as digital decoding logic that is complex but physically compact to control the switching of these analog elements to create the particular analog value. The implementation of the proposed bitstream converter replaces this system with an almost purely digital system, of a complexity and physical size that is actually smaller than the existing DAC logic. It removes not only a large area of silicon, but because of the nature of the bitstream converter, it does not require the extensive testing to guarantee the dynamic non-linearity, a problem in standard DACs using matched elements. The prior art DAC used a multiplicity of switched resistors, and to guarantee dynamic non-linearity, integral non-linearity and monotonicity specifications, each potential DAC value is required to be tested, which implies significant test time and significant impact on cost. It further makes increasing the bit

accuracy (e.g. moving from 14 bit to 16 bit) a difficult and expensive change. These prior art DACs constitute also a significant source of design effort and risk as products are continually redesigned on newer process technology. A digital modulator is a fairly simple block to design and verify, and takes virtually no effort to migrate with improvements in process technology. Although the effective DAC implemented with the present invention can have a variety of errors, the system automatically calibrates for scale factor and offset errors, and the bitstream technique has inherent monotonicity and can be quickly tested for non-linearity at a small number of points. The digital circuit itself can be fully tested at high speeds by standard "scan" methods of digital test. The resulting test time savings is significant.

Initial tests of performance in a working disk drive VCM control loop, using a very simple first-order implementation of the sigma-delta modulator in an FPGA and with the resultant bitstream signal injected directly into an existing system in place of the nominal output of the prior-art DAC, performance of the system was maintained with no adverse effects. The fact that the change from a normal DAC analog output to the bitstream signal caused no new control loop problems, including noise, stability, or dynamic performance issues, came as a surprise to the servo engineers involved. It was not obvious that this bitstream would prove compatible with systems designed for the prior art and certainly gave unexpected results. These engineers, being responsible both for the design of the entire servo system and for its integrated circuit implementation were skilled in both the art related to implementing modern servo systems and the implementation of systems such as digital-to-analog converters into integrated circuit form.

When first approached with this concept, engineers responsible for both servo loop and its integrated form, despite their skills and expertise in the art, initially doubted the viability of the system. Even after their initial reaction changed, as the proverbial "light bulb" went off, they would revert to being convinced that this new approach could be advantageous, but that if it really were practical, it would already be standard practice. We would argue that the reason why it has not seen widespread acceptance is simply because it is sufficiently non-obvious that it has not previously been pursued, despite its lower cost, higher accuracy and simpler overall system design.

Furthermore adding to the non-obvious aspect of the present invention, the digital implementation of the oversampling modulator allows the integration of the converter in the microcontroller as a hardware or software structure, since the common decimation filter used for oversampling converters is not needed. The filtering action embedded in the motor actuator low frequency response is adequate to warrant the elimination of a dedicated decimation filter. This replacement of a full DAC subsystem with only the digital modulator and allowing the filtering function to be subsumed by the low-pass nature of the system is likewise an aspect not found in prior art. This near complete elimination of precision analog components is "too good to be true" as seen by practitioners in the art, hence non-obvious.

The digital implementation of the oversampling modulator embedded into the microcontroller, either as hardware or as a software structure, may seem obvious to those familiar with modern microcontrollers. It is generally possible to add into a microcontroller a reasonable bit of analog circuitry in the form of A/D and D/A converters. These are generally either fairly low performance, or a significant added

cost both for the silicon real estate and for the need to do precision analog testing, a procedure not generally well suited to the test environment used for complex, high speed digital systems used for microcontrollers. The non-obvious aspect of our technology is that the sigma-delta, in moving back into the microcontroller, is **not** moving an analog function back into the controller, but actually relegating a newly simplified digital task back into this complex digital chip, reducing the incremental cost of adding the converter to near zero. Further, as a simple computation, the conversion from a slowly updated multi-bit word to a high frequency bitstream can in principle be managed in software, utilizing only a serial digital I/O to output the bitstream. This is not made obvious by prior art implementations of DACs in silicon on prior art microcontrollers.

The examiner has alluded to the fact that implementing a DAC in software might be obvious. The applicants are perplexed at how prior-art software controlling a digital microcontroller might somehow convert a digital signal to an analog value without the inclusion of an analog output function, i.e. a hardware DAC. Pulse width modulated digital signals have been used as digital signals with analog representation, but as explained in the subject invention specification, PWM signals, lacking noise shaping as in sigma-delta modulated bitstreams, have very poor performance and are precluded the obtaining of the benefits of the present invention. Even microcontrollers with PWM outputs tend to implement these blocks as hardware rather than software.

The novel physical features of the New Claims produce new and unexpected results and hence are unobvious and patentable over these references under § 103.

Therefore the applicants submit that Claims 7 through 18 are allowable over the cited references and respectfully solicit reconsideration and allowance.

Conclusions

For all the above reasons, applicants submit that the specifications and claims are now in proper form, and that the claims all define patentably over the prior art. Therefore they submit that this application is now in condition for allowance, which action they respectfully solicit.

Conditional Request For Constructive Assistance

Applicants have amended the claims of this application so that they are proper, definite, and define novel structure which is also unobvious. If, for any reason this application is not believed to be in full condition for allowance, applicants respectfully request the constructive assistance and suggestions of the Examiner pursuant to M.P.E.P. § 2173.02 and § 707.07(j) in order that the undersigned can place this application in allowable condition as soon as possible and without the need for further proceedings.

Very respectfully,

Carl Sawtell | **Paolo Menegoli**